GEM and Silicon Detectors for Compass

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In the fixed target experiment Compass at Cern/Sps, the reconstruction of particle tracks in a 2-stage magnetic spectrometer is planned with an angular resolution down to 10 μrad (for small scattering angles) and a spatial resolution down to 7 μm [1]. The tracking system consists of a set of **L**arge **A**ngle **T**rackers (**LAT**) covering the outer region with lowest track density and **S**mall **A**ngle **T**rackers (**SAT**) for the inner regions. In one tracking station three different detector types are staggered where each smaller one covers with some overlap the hole in the next larger one to provide better resolution and higher rate capability. Our group at the TUM is involved in the development and setup of two of the SAT, namely the GEM and the silicon microstrip detectors.

The desired high rate of $\sim 10^8$particles/s requires radiation hard detectors with a good timing resolution and a suitable readout system, capable of standing an event rate up to 100 kHz. The electronics specifically designed for this purpose must be intrinsically deadtime free and is presented separately below. The challenge of the subsequent data acquisition system is also in responsibility of our group and is covered in [2].

GEM detectors (Gaseous Electron Multiplier) consist of cascaded copper-clad, perforated Kapton foils (s. Fig.1), placed between a cathode foil and a readout layer (for reference to this recent development in the Cern gas detector group, s. [3,4]). A voltage chain in steps of $\Delta U \approx 500$ V is applied between the single copper layers, the foils and the cathode foil, with the readout layer remaining on ground potential.

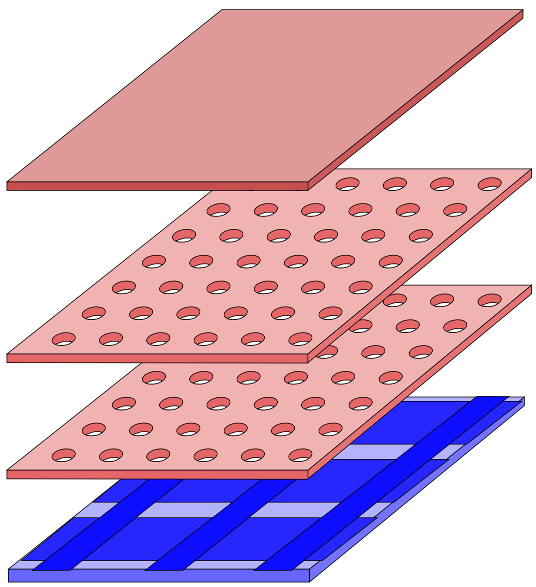

Fig. 1: Principle of a double GEM detector, with amplification in two cascaded GEM foils

A particle passing through the detector leaves primary electrons from ionizing the detector gas (70% argon, 30% CO_2) in the uppermost volume, from where they drift towards the readout board. In the holes of each GEM foil, gas amplification similar to the well-known avalanche effect near the anode wire in a drift chamber takes place. Cascading e.g. two GEM foils the individual gains multiply and one can obtain a total gain of up to several tens of thousands. By arranging the strips orthogonally on the readout board in two layers, each charge cluster is shared for the readout between both dimensions.

In the current design one GEM detector has an active area of 30.7×30.7 cm^2 and a pitch of 400 μm. In the final setup Compass will be equipped with 10 tracking stations à 4 projections.

In the technical run in the year 2000, a double GEM equipped with half of the readout electronics was operated at ΔU=415 V (for a complete overview, s. [5]). In Fig.2, the position of the biggest registered clusters in both coordinates are presented. Since the trigger consisted of the coincidence of two crossed scintillation counters, positioned under 45° with respect to the GEM, the rhombical shape is observed.

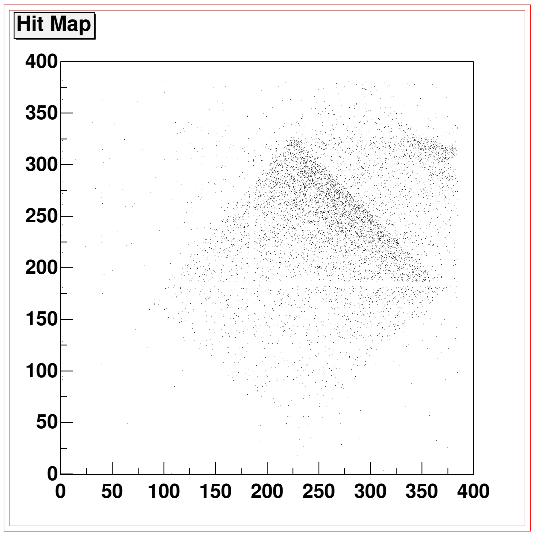

Fig. 2: Data taken with the GEM detector in the beam time 2000. Apart from the expected rhombical shape, hits are also observed close to the beam position (upper right corner). The beam itself passes through the circular deactivated zone of which a quarter is also noticable.

The further ongoing analysis concentrates on the timing structure contained in the data (s. below) and on the multiple hits as seen in the plot.

The Silicon Microstrip Detectors will be Compass' tracking components with the best spatial resolution. Combined with the other larger trackers like the GEMs they are used as the central part of the tracking stations along the spectrometer. In the hadron physics program they will be placed in addition very close before and after the target to increase the precision of the tracks of incoming and outgoing particles.

Although silicon detectors are intrinsically fairly radiation robust, the particle flux in COMPASS is so high that they would be destroyed within one year of nominal running. To avoid a constant exchange of detectors it is planned to make use of the *Lazarus Effect* [6]: at a temperature of 130 K even detectors which are unusable at room temperature are "revived" again, mainly due to the freeze out of radiation induced deep level traps. With this the life time of a silicon can be prolonged by at least a factor of 5.

Presently priority is given to the target stations. These silicon detectors have an active area of 5 × 7 cm^2, are 300 μm thick and have orthogonal readout strips with a pitch of 50 μm on the p– and n–side. The diodes were primarily designed for the HERA-B experiment [7] at DESY and can be used by us. There will be two stations before and two after the target. Each station will provide 4 projections.

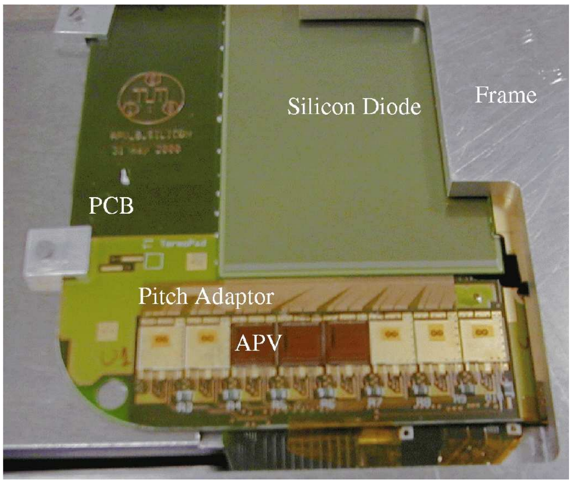

Fig. 3: Silicon detector with PCB and readout chips in a holding frame, prepared for bonding

Fig.3 shows a picture of the silicon diode, glued to the readout boards. Also shown are three readout chips APV25 and the pitch adaptor.

The PCB also includes cooling facilities: a metallic tube transferring liquid nitrogen is soldered to the backside of the board. Via the copper grounding layers inside the board the cold is transported to the silicon in a specified way.

The silicons will be housed in a low mass cryostat, which is developed in our group, the first parts are currently under test. The latest design is based on an evacuated box made out of Rohacell, a low mass foam, which is sealed with aluminized mylar foils of 30 μm thickness, supported by glass fibre structures.

In 2000 the electronics of a prototype was tested in the COMPASS environment. It was operated at room temperature and read out only single sided. As a first result, the noise performance was found to be excellent: the signal-to-noise-ratio (see fig.4) is measured to be around 28.

The Readout Electronics for GEM and silicon detectors are the same. The main feature is a practically deadtimeless readout which uses an analogue pipeline.

As frontend chip the APV25 [8] is used. It is developed for the silicon detectors of the CMS Experiment at LHC/CERN with special care for radiation hardness. With a sampling rate of 40 MHz each of the 128 input channels is stored in a 192 units long buffer (corresponds to a history of max. 4.8 μs) consisting of an array of capacitors. On request one or three of the sampled time slices can be multiplexed out on one line to the ADC. The APV also provides functions to control the sampling parameters and offers an internal calibration pulse. The intrinsic time resolution is 25 ns. Currently work is in progress to improve this value by using the information from the signal shape measured in the three time slice mode.

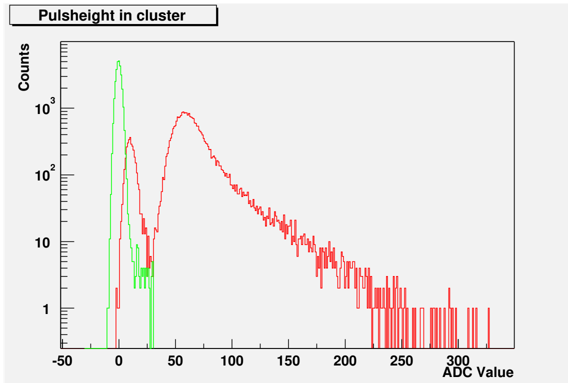

Fig. 4: Silicon Raw Signals: dark curve: signals, light curve: noise

The analogue signals are then passed to a custom made ADC system: it consists of a digitizing part (SG_ADC) and a controlling part (**GeSiCA** - **Ge**m and **Si**licon **C**ontrols and **A**quisition). The SG_ADC is a standalone card which digitizes up to 12 APVs and provides additional functionality for online filtering like pedestal correction and zero suppression. GeSiCA is a 9U VME module that distributes triggers, collects data from 4 SG_ADC cards via optical HotLink and passes data plus trigger information via optical SLink to the readout buffer (ROB) of the DAQ (see [2]). Communication with the APV is possible via VME-bus and GeSiCA.

References

[1] G. Baum *et al.*, [COMPASS Collaboration], "COMPASS: A Proposal for a Common Muon and Proton Apparatus for Structure and Spectroscopy", CERN-SPSLC-96-14

[2] L. Schmitt *et al.*, this report, p.90

[3] F. Sauli, Nucl. Instr. Meth. **A386** (1997) 531

[4] F. Sauli, A. Sharma, Ann. Rev. Nucl. Part. Sci. **49** (1999) 341

[5] B. Ketzer *et al.*, "GEM detectors for COMPASS", IEEE conference proceedings 2000

[6] `http://rd39.web.cern.ch/RD39/publications/publications.html`
RD39 Collaboration: "Charge collection efficiency of irradiated silicon detectors operated at cryogenics temperatures" Nucl. Instr. Meth. **A440** (2000) 5
RD39 Collaboration: "Charge collection efficiency and resolution of an irradiated double sided silicon microstrip detector operated at cryogenic temperatures" Nucl. Instr. Meth. **A440** (2000) 17

[7] S. Masciocchi *et al.*, Nucl. Instr. Meth **A439** (2000) 442

[8] `http://www.te.rl.ac.uk/med/apv25_web/apv25_top.html`